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Auto-Enrichener

Background of the Invention

Field of the Invention

The invention relates to a method and apparatus for enriching an engine. More particularly, the invention relates to automatically and variably enriching an all terrain vehicle engine with fuel and/or air as appropriate for different engine temperatures.

Description of Related Art

Vehicles, such as all terrain vehicles, conventionally include an engine such as an internal combustion engine in order to enable them to move under their own power. It is sometimes useful to provide additional fuel and/or air to an engine when it is running below its normal operating temperature. This may be true particularly, though not exclusively, when the engine is being started. The process of adding additional fuel and/or air is referred to herein as "enrichment", and a device for providing enrichment is referred to herein as an "enrichener".

As the term is used herein, an "all terrain vehicle" or "ATV" is defined as a motorized vehicle suitable for travel on surfaces other than paved roads or highways (though not necessarily unsuitable for travel on highways or paved roads). ATVs travel on low-pressure tires, typically four in number, and generally have a seat designed to be straddled by an operator. The seat may be designed to support one or more additional passengers in addition to the operator, and/or there may be one or more additional seats. Typically, passengers are seated in-line behind the operator. ATVs generally use handlebars for steering control.

Unless otherwise indicated, the term "vehicle" when used herein refers specifically to an all terrain vehicle.

Instances wherein enrichment may be desirable include, for example, occasions when the vehicle's engine is started while cold. Typically, the normal

operating temperature of such engines is significantly higher than the ambient temperature. When the engine is below this temperature, it may be helpful to provide the engine with additional fuel and air until such time as the engine temperature approaches its normal operating range. Once the engine reaches its operating temperature, enriching can be discontinued. Engine enrichment may be advantageous in other circumstances, as well.

It is known to manually enrich a vehicle engine. For example, a manual enrichener may be provided with a hand control, which when activated by the vehicle's operator sends additional fuel and air to the engine.

However, the manual nature of such an arrangement has several drawbacks. For example, the vehicle operator must activate the enrichener each time it is needed. If the operator does not activate a manual enrichener, no extra fuel or air will be provided. In addition, if the operator fails to deactivate a manual enrichener, or activates it when it is not needed, the engine may be supplied with unnecessarily large amounts of fuel and/or air. This may be wasteful of fuel, may make the vehicle's engine run differently than intended, etc.

A conventional manual enrichener does not in itself provide feedback to the operator as to when it should be activated. Thus, unless some feedback mechanism is provided for the operator, there may be no convenient way for the operator to tell whether enrichment is appropriate. For example, although as noted enrichment may be desirable when starting a cold engine, it may not be desirable when starting an engine that is already warm, i.e. one that was used recently and has not fully cooled down. Even assuming the vehicle operator has kept careful track of the time since the vehicle was last operated, the rate of engine cooling can depend on many factors, such as ambient temperature, wind, etc., so in many circumstances it may not be readily apparent whether the engine has cooled enough that enrichment is appropriate.

In addition, at times it may be desirable to activate the enrichener at less than full output, that is, to add fuel and air, but not at the maximum rate possible for the enrichener. For example, if the engine is started at a temperature below its operating

range, but above ambient temperature, it may be preferable to enrich the engine only slightly. Similarly, it may be desirable to vary the level of engine enrichment over time, i.e. reducing it as the engine warms.

However, for a manual enrichener, any judgment of whether to enrich the engine and to what degree must be made consciously by the operator, and likewise any adjustments to the enrichment require the operator's attention.

Attempts have been made to produce an automatic enrichener. It is possible to produce an electronic enrichener that includes an engine temperature sensor, a control processor, an adjustable enrichment valve, and an actuator for adjusting the enrichment. However, such conventional devices typically are complex and expensive to manufacture and install, and have not proven entirely satisfactory.

Summary of the Invention

It is the purpose of the claimed invention to overcome these difficulties, thereby providing an improved arrangement for automatically controlling engine enrichment.

An exemplary embodiment of an auto-enrichener in accordance with the principles of the present invention includes an enriching conduit for carrying fuel and air to an engine. A valve is disposed in the conduit, and is adjustable between at least an open configuration and a closed configuration. In the open configuration, passage of fuel and air through the conduit is enabled, while in the closed configuration passage of fuel and air through the conduit is not enabled.

The auto-enrichener also includes a thermal expansion element in communication with the valve. The thermal expansion element expands with increasing temperature and contracts with decreasing temperature. The thermal expansion element actuates the valve such that when the thermal expansion element is at a first temperature the valve is in the open configuration, and when the thermal expansion element is at a second temperature greater than the first temperature the valve is in the closed configuration.

A heater is arranged in thermal communication with the thermal expansion element.

The thermal expansion element may have a liquid portion disposed within a flexible solid portion, wherein the liquid portion expands with increasing temperature and contracts with decreasing temperature. The liquid portion may include silicone, and the flexible solid portion may include wax.

The heater may be an electric heater. The heater may be arranged in communication with the engine such that the heater heats the thermal expansion element when the engine is running, and the heater does not heat the thermal expansion element when the engine is not running.

The valve may include a valve plug movably engaged with the thermal expansion element, such that the thermal expansion element actuates the plug in order to actuate the valve between the open and closed positions. The valve may include a valve rod engaged with the valve plug and the thermal expansion element, such that when the thermal expansion element expands the rod and the plug are translated toward a closed position wherein passage of fuel and air through the conduit is not enabled so when valve is in the closed configuration, and when the thermal expansion element contracts the rod and the plug are translated toward an open position wherein passage of fuel and air through the conduit is enabled when the valve is in the open position.

In addition to being adjustable between the open and closed configurations, the valve may be adjustable to and from at least one intermediate configuration. In the intermediate configuration, passage of fuel and air through the conduit is enabled, but the rate of passage of fuel and air through the conduit when is less than the rate of passage of fuel and air through the conduit when the valve is in the open configuration. In such an arrangement, when the thermal expansion element is at a third temperature greater than the first temperature but less than the second temperature, the valve is in the intermediate configuration.

An auto-enrichener in accordance with the principles of the present invention may be incorporated into a vehicle, such as an all terrain vehicle.

A method for controlling engine enrichment in accordance with the principles of the present invention includes providing an enriching conduit for carrying fuel and air to an engine, and providing a valve disposed in the conduit. The valve is adjustable between at least an open configuration and a closed configuration, wherein in the open configuration passage of fuel and air through the conduit is enabled, and in the closed configuration passage of fuel and air through the conduit is not enabled.

The method includes providing a thermal expansion element in communication with the valve. The thermal expansion element expands with increasing temperature and contracts with decreasing temperature, such that the thermal expansion element actuates the valve. When the thermal expansion element is at a first temperature the valve is in the open configuration, and when the thermal expansion element is at a second temperature greater than the first temperature the valve is in, or at least is beginning to move towards, the closed configuration.

The method also includes providing a heater in thermal communication with the thermal expansion element.

The method further includes heating the thermal expansion element with the heater when the engine is running, and not heating the thermal expansion element when the engine is not running. Thus, while the vehicle is running the valve is actuated toward the closed configuration, and while the vehicle is not running the valve is actuated toward the open configuration.

The thermal expansion element may have a liquid portion disposed within a flexible solid portion, wherein the liquid portion expands with increasing temperature and contracts with decreasing temperature. The liquid portion may include silicone, and the flexible solid portion may include wax.

The heater may be an electric heater. The heater may be arranged in communication with the engine such that the heater heats the thermal expansion element when the engine is running, and the heater does not heat the thermal expansion element when the engine is not running.

The valve may include a valve plug movably engaged with the thermal expansion element, such that the thermal expansion element actuates the plug in order to actuate the valve between the open and closed positions. The valve may include a valve rod engaged with the valve plug and the thermal expansion element, such that when the thermal expansion element expands the rod and the plug are translated toward a closed position wherein passage of fuel and air through the conduit is not enabled when the valve is in the closed configuration, and when the thermal expansion element contracts the rod and the plug are translated toward an open position wherein passage of fuel and air through the conduit is enabled when the valve is in the open position.

In addition to being adjustable between the open and closed configurations, the valve may be adjustable to and from at least one intermediate configuration. In the intermediate configuration, passage of fuel and air through the conduit is enabled, but the rate of passage of fuel and air through the conduit when is less than the rate of passage of fuel and air through the conduit when the valve is in the open configuration. In such an arrangement, when the thermal expansion element is at a third temperature greater than the first temperature but less than the second temperature, the valve is in the intermediate configuration.

Brief Description of the Drawings

Like reference numbers generally indicate corresponding elements in the figures.

Figure 1 shows in schematic form a vehicle having an exemplary embodiment of an auto-enrichener in accordance with the principles of the present invention.

Figure 2 shows an exemplary embodiment of an auto-enrichener in accordance with the principles of the present invention, in an open configuration.

Figure 3 shows the auto-enrichener of Figure 2 in a closed configuration.

Figure 4 shows the auto-enrichener of Figure 2 in an intermediate configuration.

Figures 5A-5C show a magnified view of an exemplary embodiment of a thermal expansion element for an auto-enrichener in accordance with the principles of the present invention, with the auto-enrichener in the open, intermediate, and closed configurations respectively.

Figures 6A-6C show a magnified view of another exemplary embodiment of a thermal expansion element for an auto-enrichener in accordance with the principles of the present invention, with the auto-enrichener in the open, intermediate, and closed configurations respectively.

Detailed Description of the Preferred Embodiment

Figure 1 shows an all-terrain vehicle **10** with an exemplary embodiment of an auto-enrichener **12** therein. For the sake of clarity, the vehicle **10** and the components thereof are shown in schematic form. Actual all-terrain vehicles **10** may vary in size, shape, and structure.

As may be seen from Figure 1, the auto-enrichener **12** is in communication with the engine **14** and the air/fuel supply **16**. Typically, air and fuel for the normal operation of the engine **14** pass from the air/fuel supply **16** to the engine **14** without passing through the auto-enrichener **12**, though this arrangement is not illustrated herein.

When the auto-enrichener **12** is in operation, additional air and fuel passes from the air/fuel supply **16** to the engine **14** via the auto-enrichener **12**. When the auto-enrichener **12** is not in operation, no additional air and fuel passes from the air/fuel supply **16** to the engine **14** via the auto-enrichener **12**. However, it is emphasized that the operation or lack of operation of the auto-enrichener **12** at a particular time does not necessarily affect the normal transmission of air and fuel to the engine **14**. Thus, even if the auto-enrichener **12** is not in operation, air and fuel may reach the engine **14** from the air/fuel supply **16** by other routes.

Depending on the particular embodiment of the vehicle **10**, a variety of engines **14** may be suitable. Suitable engines include, but are not limited to, two-stroke

and four-stroke engines. Suitable engines are known per se, and are not described further herein.

Likewise, a variety of air/fuel supplies **16** may be suitable. Suitable air/fuel supplies include, but are not limited to, carburetors and fuel injectors. Suitable air/fuel supplies are known per se, and are not described further herein.

Figure 2 shows the auto-enrichener **12** in greater detail. As in Figure 1, the engine **14** and the air/fuel supply **16** are shown in schematic form for simplicity.

The auto-enrichener **12** includes an enriching conduit **20**, arranged to carry air and fuel to the engine **14**.

A valve **22** is disposed in the conduit **20** so as to control the flow of fuel and air through the conduit **20**. In the exemplary arrangement illustrated, the valve **22** is so positioned as to divide the conduit **20** into first and second sections **20A** and **20B**. However, this is exemplary only. Either or both the valve **22** and the conduit **20** may be configured and arranged so that there are more than two conduit sections or fewer than two sections.

The valve **22** is adjustable between at least an open configuration, wherein the passage of air and fuel into the engine **14** is enabled, and a closed configuration. wherein the passage of air and fuel into the engine **14** is not enabled.

As illustrated in Figure 2, the valve **22** is in the open configuration. Thus, the passage of a flow **18** of air and fuel through the conduit **20** and the valve **22**, and thus through the auto-enrichener **12**, is enabled. In the arrangement shown, the flow **18** is illustrated in two sections. Air and fuel flow along path **18A** from the air/fuel supply **16** through the first section **20A** of the conduit **20** to the valve **22**, and then flow along path **18B** from the valve **22** through the second section **20B** of the conduit **20** to the engine **14**. As previously noted, such an arrangement is exemplary only. However, in such an arrangement a flow **18** of additional air and fuel is provided to the engine **14**, thus enriching the engine **14**.

Figure 3 shows the valve **22** in the closed configuration. The passage of air and fuel through the conduit **20** and the valve **22**, and thus through the auto-

enrichener **12**, is not enabled. In such an arrangement no additional air and fuel is provided to the engine **14** through the auto-enrichener **12**, and thus the engine **14** is not enriched.

As shown in Figures 2 and 3, the valve **22** includes a valve plug **24** that is movable between an open position, shown in Figure 2, and a closed position, shown in Figure 3. In the open position, the valve plug **24** does not obstruct the passage of air and fuel through the valve **22**, and thus the valve **22** is in the open configuration. In the closed position, the valve plug **24** obstructs the passage of air and fuel through the valve **22**, and thus the valve **22** is in the closed configuration.

In addition, as shown in Figures 2 and 3 the valve **22** includes a valve rod **26** connected to the valve plug **24** so that as the rod **26** moves, the plug **24** also moves.

However, such an arrangement for the valve **22** is exemplary only. Other valves **22** having other arrangements may be equally suitable.

As shown in Figures 2 and 3, the auto-enrichener **12** also includes a thermal expansion element **28**. The thermal expansion element **28** expands as its temperature increases, and contracts as its temperature decreases. A variety of structures and compositions for the thermal expansion element **28** may be suitable. The structure and composition for the thermal expansion element **28** is described in greater detail below.

The thermal expansion element **28** is in communication with the valve **22**. The communication therebetween is such that as the temperature of the thermal expansion element **28** increases, and the size of the thermal expansion element **28** likewise increases, the valve **22** is urged towards the closed configuration. Furthermore, as the temperature of the thermal expansion element **28** decreases, and the size of the thermal expansion element **28** likewise decreases, the valve **22** is urged towards the open configuration.

Depending on the particular structure and composition of the valve **22** and the thermal expansion element **28**, there will be some first temperature such that

when the valve **22** is at or below the first temperature the valve **22** is in the open configuration. Likewise, there will be some second temperature such that when the valve **22** is at or above the first temperature the valve **22** is in the closed configuration. For a thermal expansion element **28** having a positive coefficient of thermal expansion, the second temperature will be greater than the first temperature.

As shown in Figures 2 and 3, the thermal expansion element **28** engages the valve rod **26** indirectly, via a volume of oil **34**. As may be seen by a comparison of Figures 2 and 3, when the thermal expansion element **28** increases in size, i.e. when heated, it displaces the oil **34**, which in turn displaces the rod **26**. This then causes the valve plug **24** to translate towards the closed position, placing the valve **22** into the closed configuration wherein it does not enable the flow **18** of air and fuel therethrough to the engine **14**.

Conversely, when the thermal expansion element **28** decreases in size, i.e. as it cools, it draws in the oil **34**, which in turn draws in the rod **26**. This then causes the valve plug **24** to translate towards the open position, placing the valve **22** into the open configuration in which it allows the flow **18** of air and fuel therethrough to the engine **14**.

In certain embodiments, the valve plug **24** may be biased toward the open position, for example by an elastic member such as a spring, by negative pressure in the oil, etc. In such an arrangement, the valve plug **24** would tend to remain in and/or move toward the open position unless it is driven towards the closed position as the thermal expansion element **28** is heated. However, such an arrangement is exemplary only.

Furthermore, this overall arrangement also is exemplary only. Other arrangements may be equally suitable. In particular, auto-enricheners **12** including but not limited to those that do not use oil **34**, for example arrangements wherein the thermal expansion element **28** actuates the valve **22** directly, may be suitable.

As may also be seen from Figures 2 and 3, the auto-enrichener **12** includes a heater **36** that is in thermal communication with the thermal expansion element **28**. The heater **36** is adapted to operate when the engine **14** operates.

For example, as illustrated the heater **36** is an electric resistance heater, and is connected by wires **38** to the engine **14**. When the engine **14** runs, electrical power is directed to the heater **36** via the wires **38**. As shown, the wires **38** connect to the engine **14** itself, and draw current from the electrical system of the engine **14**. However, such an arrangement is exemplary only. Other arrangements may be equally suitable. In particular, arrangements wherein the heater **36** is not an electrical heater may be equally suitable. In such arrangements, heat may be derived from other sources, such as the ambient heat of the engine **14** itself.

Regardless of the source of the heat, as the heater **36** heats the thermal expansion element **28**, the thermal expansion element **28** expands, and the valve **22** is urged towards the closed configuration wherein a flow **18** of additional air and fuel is not delivered to the engine **14** therethrough. By contrast, when the heater **36** does not heat the thermal expansion element **28**, the thermal expansion element **28** cools and contracts, and the valve **22** is urged towards the open configuration wherein a flow **18** of additional air and fuel is delivered to the engine **14** therethrough.

Because the heater **36** is activated when the engine **14** runs, the auto-enrichener **12** is self-controlling, and does not require activation or adjustment by the operator of the vehicle **10**.

For example, when the engine **14** is cold, as when the vehicle has not been used for some period of time, the thermal expansion element **28** likewise will be cold. Consequently, the auto-enrichener **12** will deliver additional air and fuel to the engine **14** if it is started under such conditions, as may be desirable when the engine **14** is cold.

By contrast, when the engine **14** is hot, as when the vehicle has been used recently, the thermal expansion element **28** likewise will be hot. Consequently, the

auto-enrichener **12** will not deliver additional air and fuel to the engine **14** if it is started under such conditions, as may be desirable when the engine **14** is hot.

Thus, because the relative temperature of the thermal expansion element **28** mimics that of the engine **14**, the auto-enrichener **12** delivers or does not deliver additional air and fuel to the engine **14** as appropriate for the engine conditions.

It is noted that the temperature of the engine **14** itself is not necessarily being measured, nor is it necessary for the temperature of the engine **14** to even be known in order for the auto-enrichener **12** to operate. Furthermore, it is not necessary for the temperature of the thermal expansion element **28** to be equal to the temperature of the engine **14**, or even to be approximately similar, though for some embodiments this may be the case.

It is only the relative temperatures that must correspond. That is, when the engine **14** is cold, the thermal expansion element **28** must be cold, and when the engine **14** is hot, the thermal expansion element **28** must be hot. More particularly, when the engine **14** is cold, the thermal expansion element **28** must be at some first temperature such that the valve **22** is in the open configuration, and when the engine **14** is cold, the thermal expansion element **28** must be at some second temperature such that the valve **22** is in the closed configuration.

Turning to Figure 4, the auto-enrichener **12** may be movable to and from an intermediate configuration, in addition to the open and closed configurations shown in Figures 2 and 3, respectively. As may be seen in Figure 4, the thermal expansion element **28** is at some size intermediate to its small size when cold as shown Figure 2 and its large size when hot as shown in Figure 3. Such an arrangement may be suitable for certain embodiments, although it is exemplary only.

The intermediate size for the thermal expansion element **28** is achieved when the thermal expansion element **28** is at some third temperature intermediate to the first and second temperatures. As may be seen, in such an instance a flow **18** of additional air and fuel through the valve **22** and thus to the engine **14** via the auto-enrichener **12** is still enabled. However, a comparison of Figures 2 and 4 reveals that

the flow **18** in the intermediate configuration is less than that in the open configuration. As illustrated, this is accomplished by having a reduced area for the conduit **20** when the valve **22** is in the intermediate configuration, as compared with the open configuration. Consequently, the rate of passage of air and fuel through the conduit **20** is less when the valve **22** is in the intermediate configuration than when the valve **22** is in the open configuration.

The intermediate configuration is achieved when the thermal expansion element **28** is warmer than in the open configuration, but cooler than in the closed configuration. This condition is obtained when the heater **36** has been operating in the past, but has not operated recently enough that the thermal expansion element **28** is still fully expanded, did not operate for a long enough period that the thermal expansion element **28** is fully expanded, etc.

It is noted that operation in the intermediate configuration may be transient. That is, the valve **22** will not necessarily stop at or hold steady in the intermediate configuration. Rather, as the temperature of the thermal expansion element **28** continues to increase, the valve **22** may continue to move towards the closed position. Thus, although the valve **22** may be in the intermediate configuration at some point or for some period of time, this should not be taken to imply that the valve **22** will remain fixed in the intermediate configuration.

It is also noted that the valve **22** may begin in the intermediate position when the engine **14** is started. For example, if the engine **14** has been operated in the past, but has been inactive for some period of time since then, the thermal expansion element **28** may have cooled sufficiently for the valve **22** to be in the intermediate configuration when the engine **14** is again started. Of course, if the period of inactivity is sufficiently long, and/or local temperatures are sufficiently low, the valve **22** might be in the open configuration when the engine **14** is started. Likewise, if the engine **14** is restarted after a relatively short time, the valve **22** might be in the closed configuration when the engine **14** is restarted.

Thus, although the valve **22** typically will tend to move towards the closed configuration as the engine operates **14**, the valve **22** may be in substantially any configuration when the engine **14** is started.

Because the heater **36** operates when the engine **14** operates, the intermediate configuration thus occurs when the engine **14** is warmer than at a typical ambient temperature, but cooler than its normal operating temperature.

Thus, when the engine **14** is in such a condition, if the engine **14** is made to operate the engine **14** will be enriched, but not to the degree it would be enriched if it were started cold with the auto-enrichener **12** in the open configuration.

Therefore, again because the relative temperature of the thermal expansion element **28** mimics that of the engine **14**, the auto-enrichener **12** delivers or does not deliver variable amounts of additional air and fuel to the engine **14** as appropriate for the engine conditions.

Depending on the embodiment, it may be advantageous to arrange for the auto-enrichener **12** to be continuously variable, such that the amount of additional fuel and air delivered to the engine **14** therethrough is also continuously variable depending on the temperature of the engine **14**. The arrangement illustrated in Figures 2-4 is such an arrangement.

However, this is exemplary only. In other arrangements, the auto-enrichener **12** to be discretely variable, such that only a few different amounts of additional fuel and air are delivered to the engine **14** therethrough depending on the temperature of the engine **14**.

The particular structure and composition of the thermal expansion element **28** may vary from embodiment to embodiment. As illustrated in Figures 2-4, the thermal expansion element **28** is of essentially uniform composition. However, such an arrangement is exemplary only.

Figures 5A-5C show an alternative embodiment of the thermal expansion element **28**. Figure 5A shows a portion of the auto-enrichener **12** with the valve in the open configuration, with the thermal expansion element **28** having a

relatively small size as when the thermal expansion element **28** is at the first temperature (cold). Figure 5B shows a portion of the auto-enrichener **12** with the valve in the intermediate configuration, with the thermal expansion element **28** having an intermediate size as when the thermal expansion element **28** is at the third temperature (warm). Figure 5C shows a portion of the auto-enrichener **12** with the valve in the closed configuration, with the thermal expansion element **28** having a relatively large size as when the thermal expansion element **28** is at the second temperature (hot).

As shown therein, the thermal expansion element **28** includes a liquid portion **30** disposed within a flexible solid portion **32**. The liquid portion **30** has a high coefficient of thermal expansion, and thus expands and contracts to a large degree with changing temperature, as may be seen by a comparison of Figures 5A-5C. Thus, the liquid portion **30** is responsible for the greater part of the expansion and contraction of the thermal expansion element **28**. In the embodiment shown in Figures 5A-5C, the flexible solid portion **32** encapsulates and contains the liquid portion **30**, but does not necessarily contribute substantially to the expansion and contraction of the thermal expansion element **28**.

For such a thermal expansion element **28**, a variety of liquids and flexible solids may be suitable. For example, suitable liquids for the liquid portion **30** include, but are not limited to, liquid silicones. Alternatively, the liquid portion may include wax, and/or may include a mixture of wax and silicone, including but not limited to mixtures such as suspensions or emulsions of otherwise immiscible waxes and/or silicones. Suitable solids for the flexible solid portion **32** include, but are not limited to, wax. Similarly, the flexible solid portion may include wax, but alternatively may include a mixture of wax and silicone. It is to be understood that suitability of solids and liquids will depend at least in part on their particular physical properties, i.e. their relative melting and boiling points, the coefficients of thermal expansion, their relative tendency to react with one another, etc.

In the arrangement illustrated in Figures 5A-5C, the liquid portion is contiguous within the thermal expansion element **28**. However, this is exemplary only.

Figures 6A-6C show another alternative embodiment of the thermal expansion element **28**. Figures 6A-6C generally correspond to Figures 5A-5C in terms of temperature and configuration of the valve **22**. Also, as in Figures 5A-5C, in Figures 6A-6C the thermal expansion element **28** includes a liquid portion **30** disposed within a flexible solid portion **32**.

However, while the liquid portion **30** is contiguous in Figures 5A-5C, in Figures 6A-6C the liquid portion is distributed into several discrete portions.

Despite this difference in structure, the overall performance of the thermal expansion element **28** in Figures 6A-6C is similar that of Figures 5A-5C. The liquid portion **30** again has a high coefficient of thermal expansion, and thus expands and contracts to a large degree with changing temperature. However, as may be seen by a comparison of Figures 6A-6C, each discrete portion of the liquid portion **30** expands and contracts with increasing and decreasing temperature. Thus, the liquid portion **30** remains responsible for the greater part of the expansion and contraction of the thermal expansion element **28**. Likewise, in the embodiment shown in Figures 6A-6C, the flexible solid portion **32** again encapsulates and contains the liquid portion **30**, but does not necessarily contribute substantially to the expansion and contraction of the thermal expansion element **28**.

Thus, even given a particular material or combination of materials, the thermal expansion element **28** may vary considerably from embodiment to embodiment. Furthermore, both the structures and the compositions illustrated in Figures 5A-C and 6A-C and described herein are exemplary only. Other arrangements may be equally suitable.

The above specification, examples and data provide a complete description of the manufacture and use of the composition of the invention. Since many embodiments of the invention can be made without departing from the spirit and scope of the invention, the invention resides in the claims hereinafter appended.